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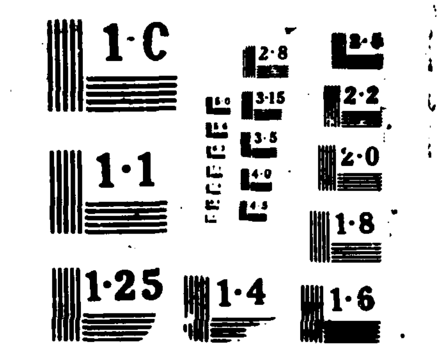
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The problem of reliable communication in the presence of extreme and unpredictable fading was studied using the techniques of broadcast coding. It was shown that for low signal-to-noise ratios, the sophisticated broadcast coding strategies devised by Cover and others may not be signficantly superior to the much simpler class of timesharing strategies. Papers included such titles as "A note on the wideband Gaussian broadcast channel" and "A model for the study of discrete memoryless very noisy channels".

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CODING FOR SPREAD-SPECTRUM CHANNELS IN THE PRESENCE OF JAMMING

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Abstract:

The long-term goal of this project is to obtain a basic mathematical understanding of the problems involved in communication in the presence of severe fading and/or hostile jamming. Our basic approach has always been to study these problems using the techniques and insights of *information theory*. In our earlier work, which was devoted to the jamming problem, we combined information theory with *game theory*, the idea being that one can view the communication process as a game between two players, the communicator and the jammer, with Shannon's mutual information serving as the payoff function. Using this technique, we obtained many insights about optimal jamming and antijamming strategies in a variety of realistic situations (Refs. [1]–[7]). More recently, we have been using (and extending) the techniques of "Broadcast Coding," a subdiscipline of information theory, to study the problems of communicating reliably in the presence of unknown or changing noise parameters. This approach has already yielded useful insights into the problems of military communications; and at the same time, it has suggested some attractive new problems in broadcast coding theory (e.g., "very noisy broadcast channels," to be mentioned below) which promise to inject new life into this speciality.

Recent Significant Results:

In reference [7], we embarked on a new direction for this project, and began an abstract study of the problem of reliable communication in the presence of extreme and unpredictable fading. There, using a remarkable recent idea of Posner (IEEE Trans. Communications, April 1983, pp. 509–517), we studied this problem using the techniques of *broadcast coding*. Broadcast coding, which was invented in 1972 by Cover, is a communication strategy which is normally applied to situations in which one individual must transmit information simultaneously to two or more receivers over two or more noisy channels. Posner's idea was to apply these results to a single physical transmitter and receiver, for which the transmission conditions are unknown, and to treat the possible transmission conditions as several "virtual" channels, corresponding the possible noise conditions. In this way, when the channel conditions are favorable, a large volume of information can be transmitted (this corresponds to transmitting over one of the "good" broadcast channels), but when conditions are unfavorable, nevertheless it is still possible to transmit critical information reliably, albeit at a slower rate (this corresponds to transmitting over one of the "bad" broadcast channels). In our paper [7], we showed that for a Gaussian broadcast channel (the broadcast channel model most appropriate for deep space and satellite communication), that for low signal-to-noise ratios, the sophisticated broadcast coding strategies devised by Cover and other researchers may not be significantly superior to the much simpler class of "timesharing" strategies. Our student, Eric Majani, has since shown that this same result (broadcast coding is not markedly superior to timesharing) is also true for very noisy binary symmetric channels. Since timesharing is much easier to implement than broadcast coding, we have begun a serious investigation of this interesting and unexpected phenomenon.

We discovered very early in this research that a serious study of very noisy broadcast channels requires a thorough understanding of very noisy (ordinary) channels. And although there is some published research on this topic, we have found nothing in the literature which is quite what we need. Therefore, in [8], we completed what we feel is the definitive study of very noisy discrete memoryless channels (DMC's). In [8], we defined a class of very noisy DMC's, where the noise is controlled by a single parameter $\epsilon \geq 0$, which we call the abstract signal-to-noise ratio. We found that DMC's fall into two different categories, one for which the capacity is proportional to ϵ, and the other for which it is proportional to ϵ^2, for small values of the signal-to-noise ratio ϵ. We have developed algorithms for calculating the constant of proportionality, for both classes of channels. We feel that this paper will prove to be the definitive work on very noisy DMC's; in any case, it is just what we need for our study of very noisy broadcast channels, which is now well underway.

In a related study, we have been making an information-theoretic investigation of the problem of optimal data compression. In [9], we have solved an outstanding problem in this subject, and computed the worst-case behavior of a certain class of quantization algorithms. And while it is too early to say exactly what practical importance this result may eventually assume, it is a nice example of how research in one area (in this case, communication in the presence of severe fading) may lead to results in another (in this case, data compression).

In summary, the research supported by this contract is closely related to the mainstream of modern spread-spectrum research, but contains many unique features. We feel that our results can contribute to greatly enhanced U.S. communications security.

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